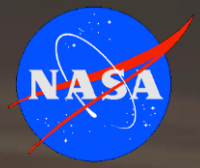


National Aeronautics and
Space Administration

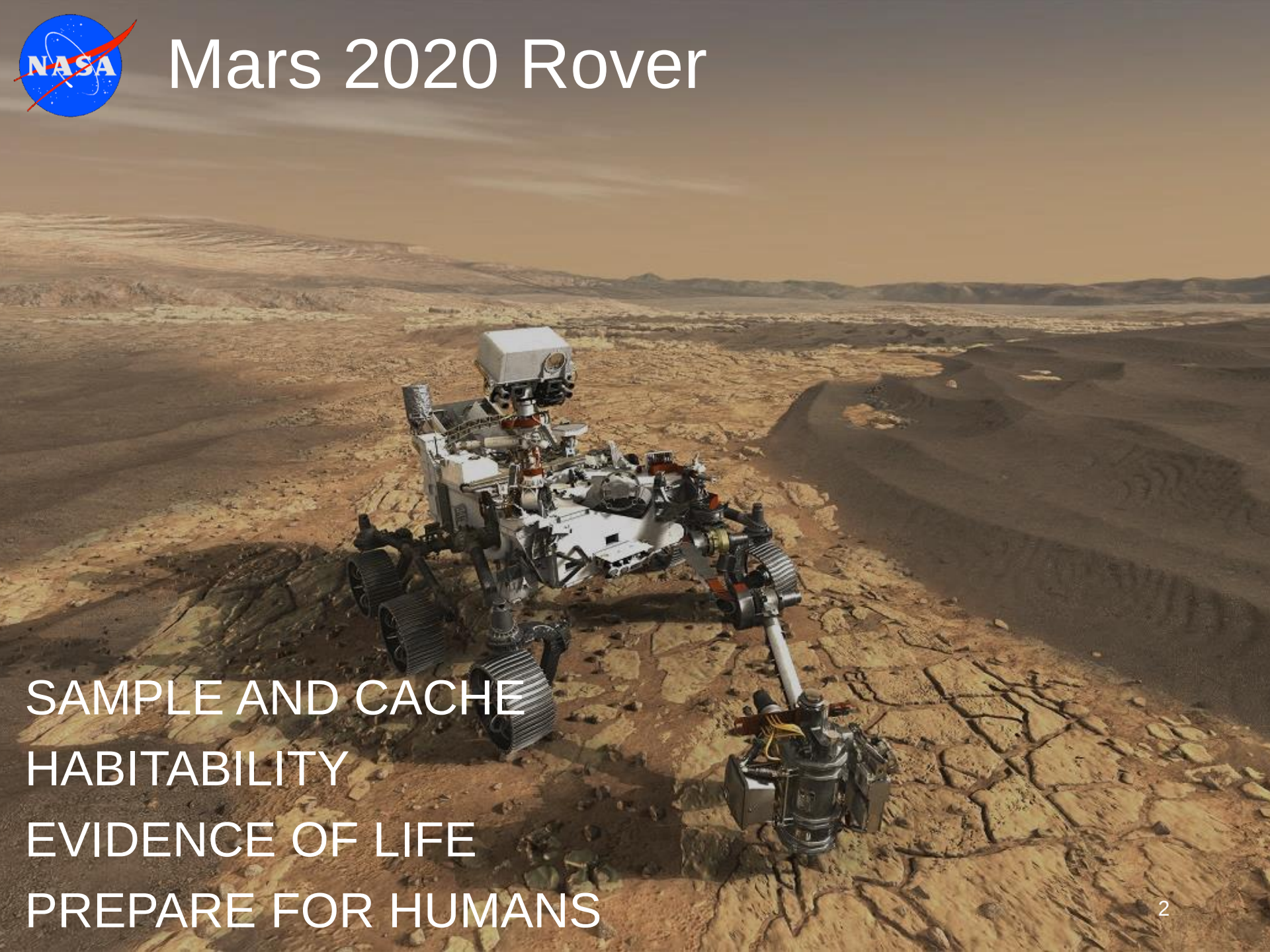
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Compatibility Tests Between the Mars Vehicle System Test Bed and RIMFAX Radar Antenna Prototype for the Mars 2020 Mission

Edward Gonzales
Elizabeth Cordoba
Jet Propulsion Laboratory, California Institute of Technology

Svein-Erik Hamran
Forsvarets forskningsinstitutt

Mars 2020 Rover



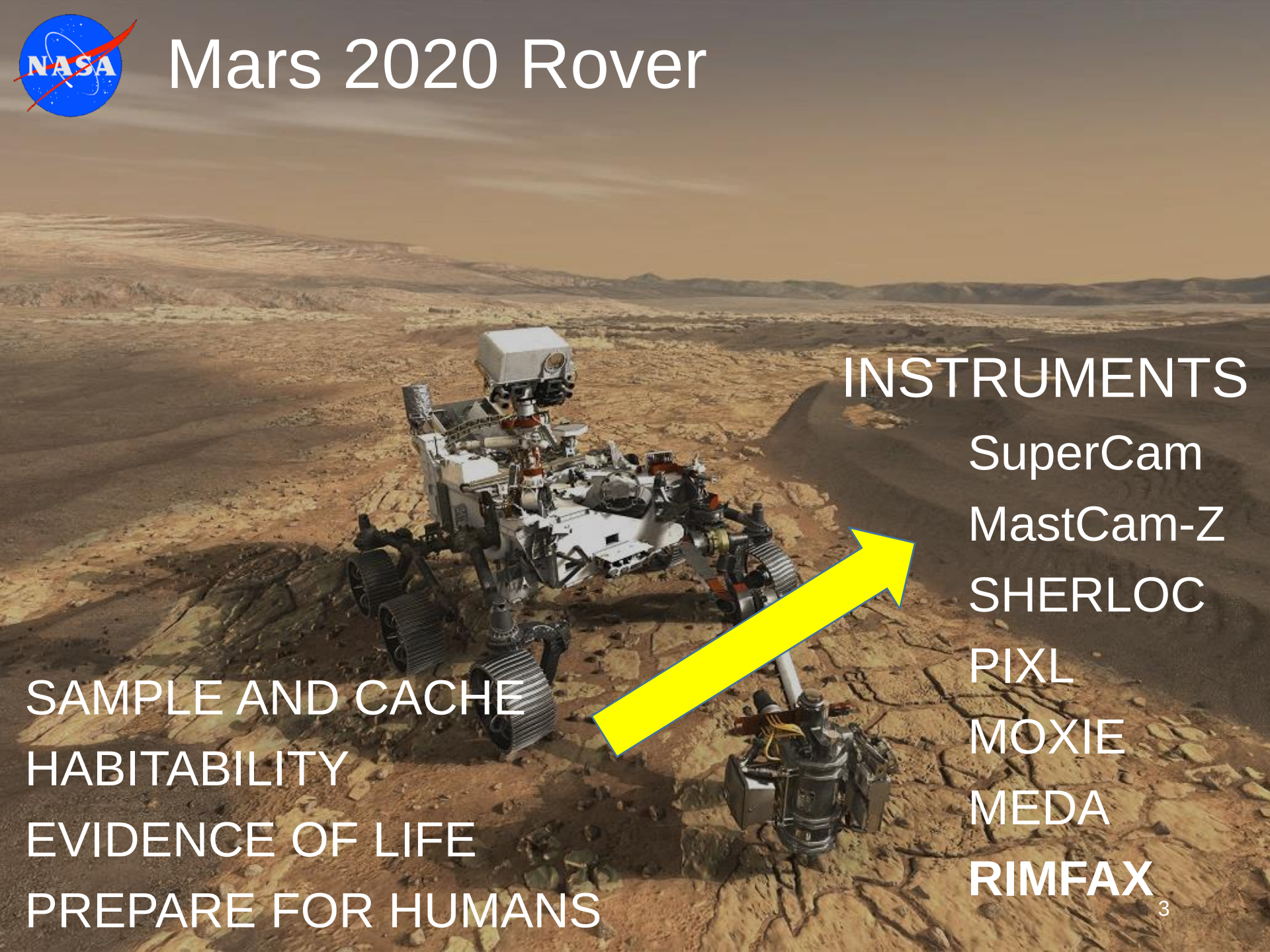
SAMPLE AND CACHE

HABITABILITY

EVIDENCE OF LIFE

PREPARE FOR HUMANS

Mars 2020 Rover



INSTRUMENTS

- SuperCam
- MastCam-Z
- SHERLOC
- PIXL
- MOXIE
- MEDA
- **RIMFAX**

SAMPLE AND CACHE

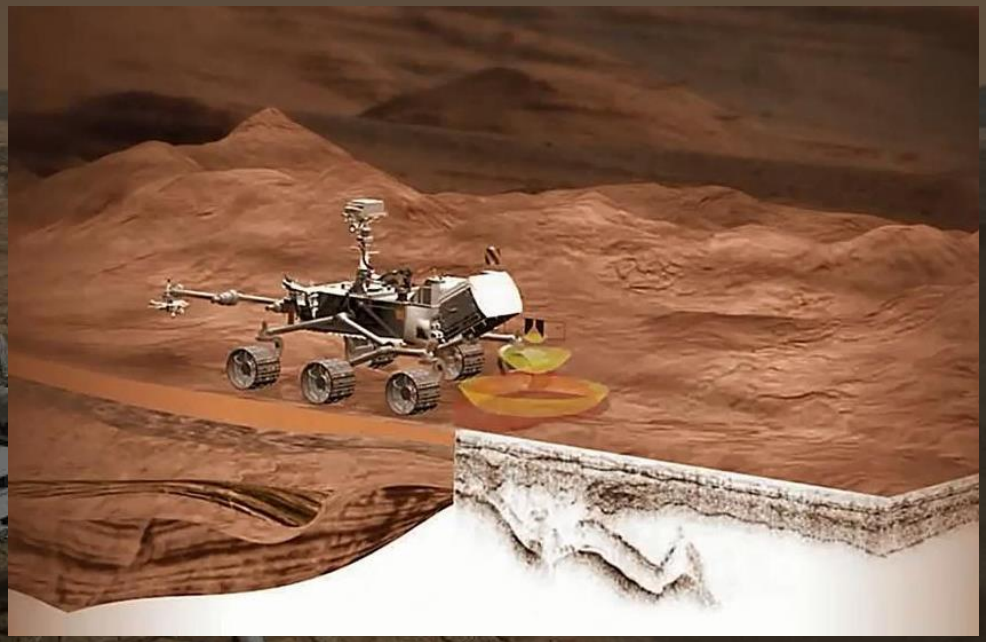
HABITABILITY

EVIDENCE OF LIFE

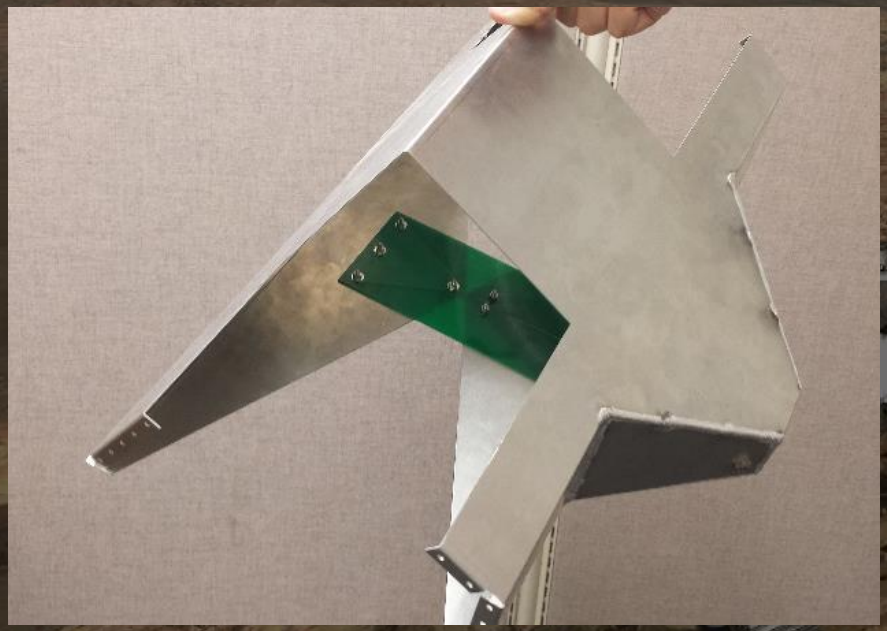
PREPARE FOR HUMANS

RIMFAX

- Radar Imager for Mars' subsurFace eXperiment
- UWB ground penetrating radar (GPR)
- Goal: analyze shallow and deep subsurface structure and composition
- 150 MHz to 1200 MHz



Compatibility concerns



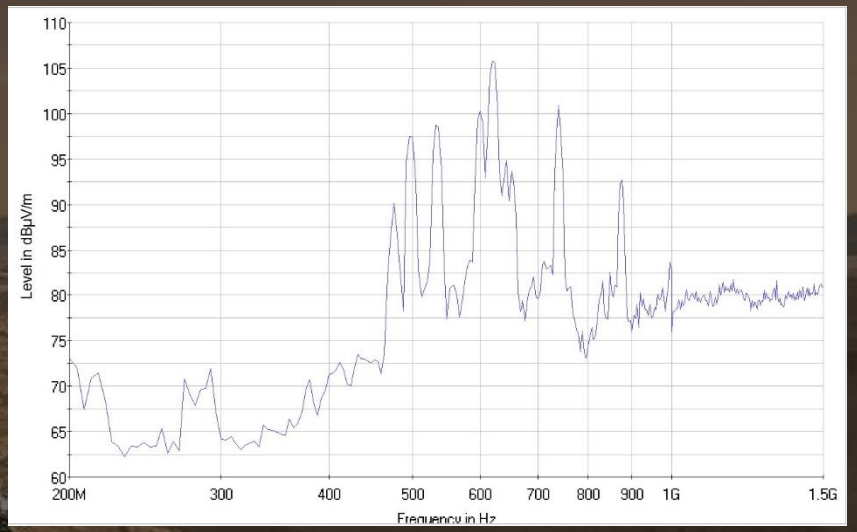
- Rover is a complex electronic system with dozens of subsystems, each generating noise
- RIMFAX is a sensitive GPR with strict scientific requirements
- Risk magnified as RIMFAX will operate during rover driving (i.e. operating many avionics subsystems concurrently)
- Will science impose additional EMC requirements?
- RIMFAX team offered prototype antenna for risk reduction tests

Test proposal

- JPL proposed tests using most accurate test bed available: Vehicle System Test Bed (VSTB) at JPL's Mars Yard.
- Place prototype antenna in proposed rover location
- Drive rover at high and low speeds (4.2 cm/s and 2.1 cm/s, respectively) while measuring received signal with spectrum analyzer emulating radar

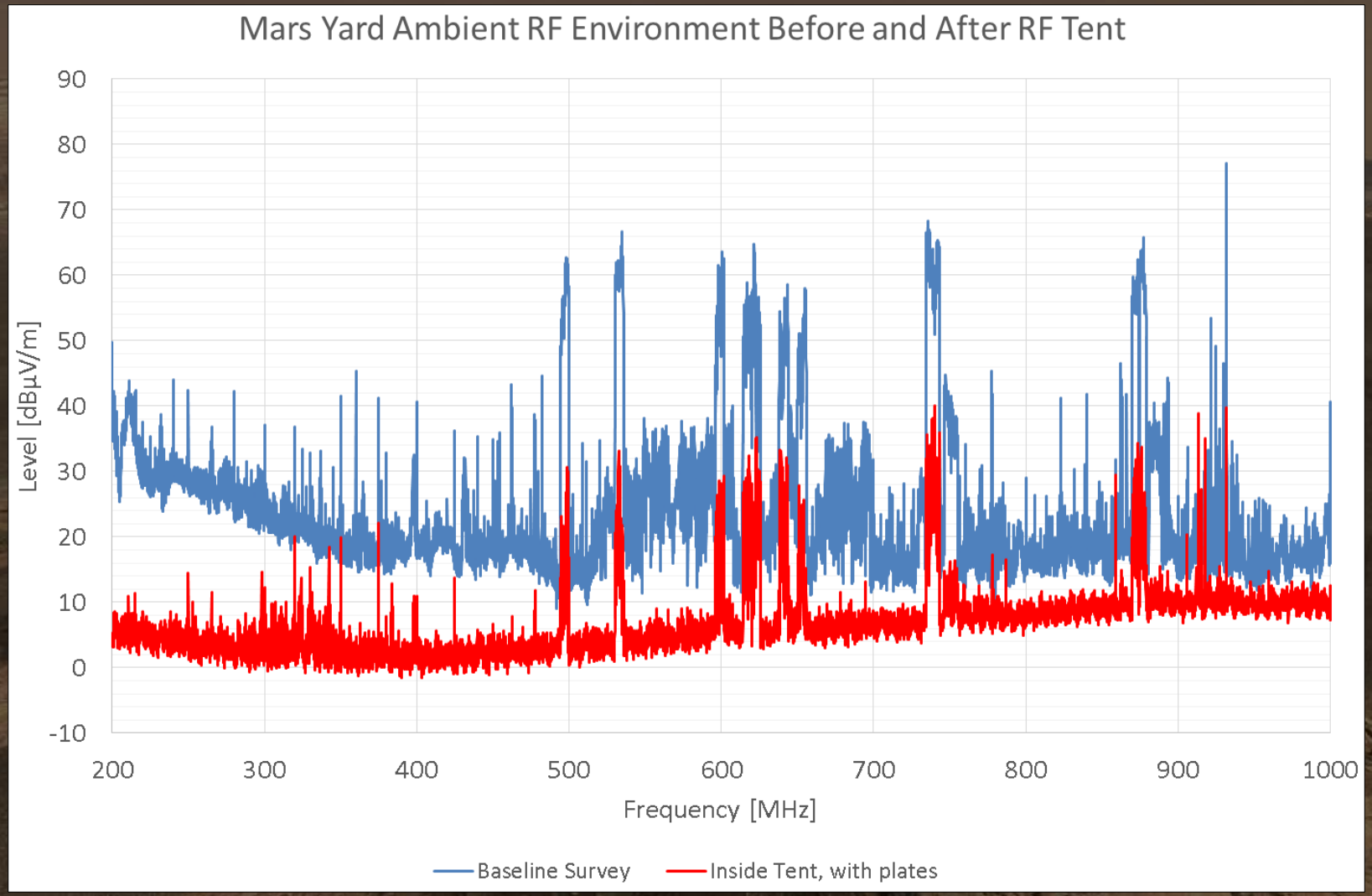
Test challenges

- JPL is close to TV transmitters serving much of Los Angeles. These occupy much of the operating range of RIMFAX
- VSTB has environmental and hardware safety restrictions.

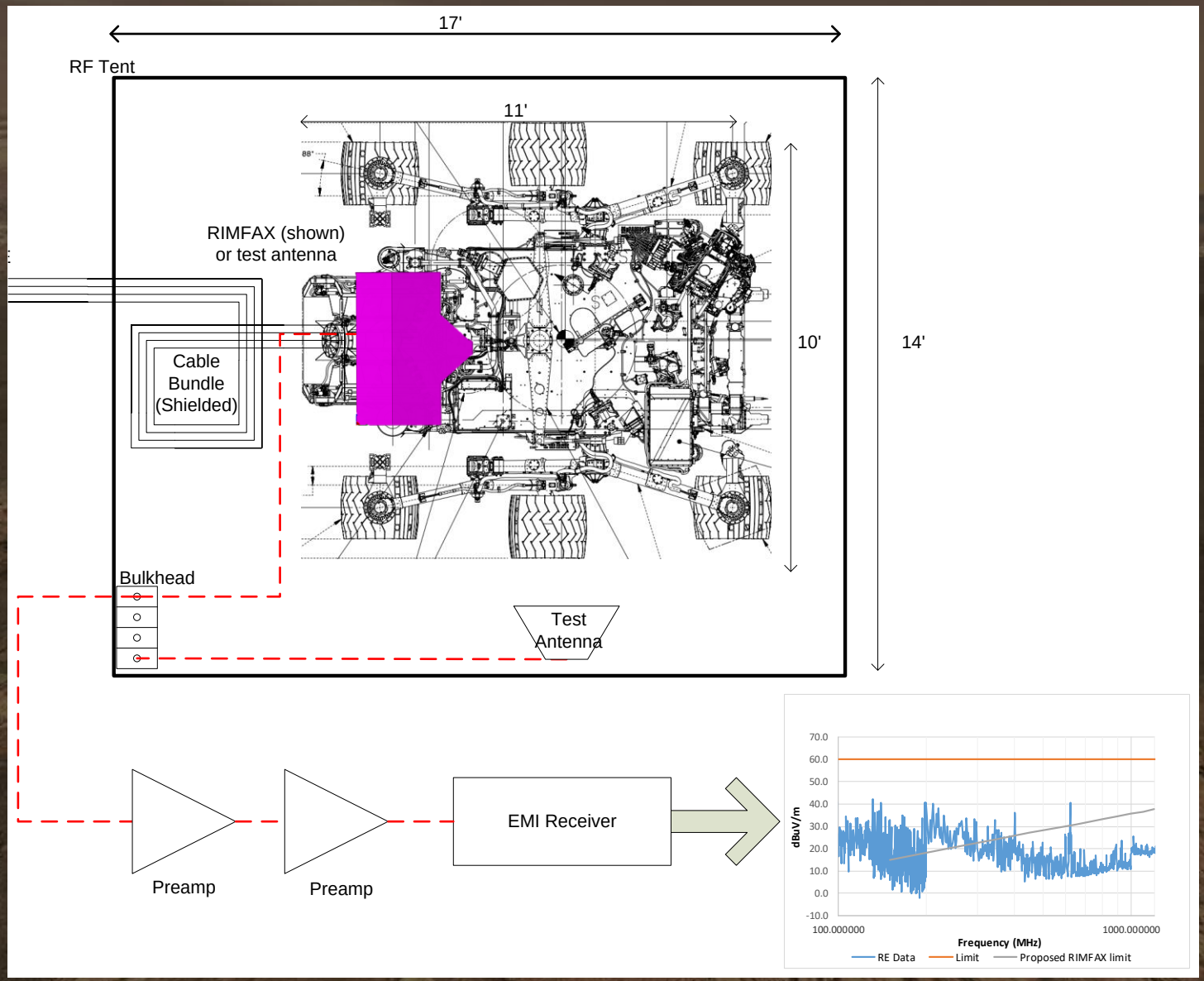


➔Custom RF tent built to fit in confines of garage

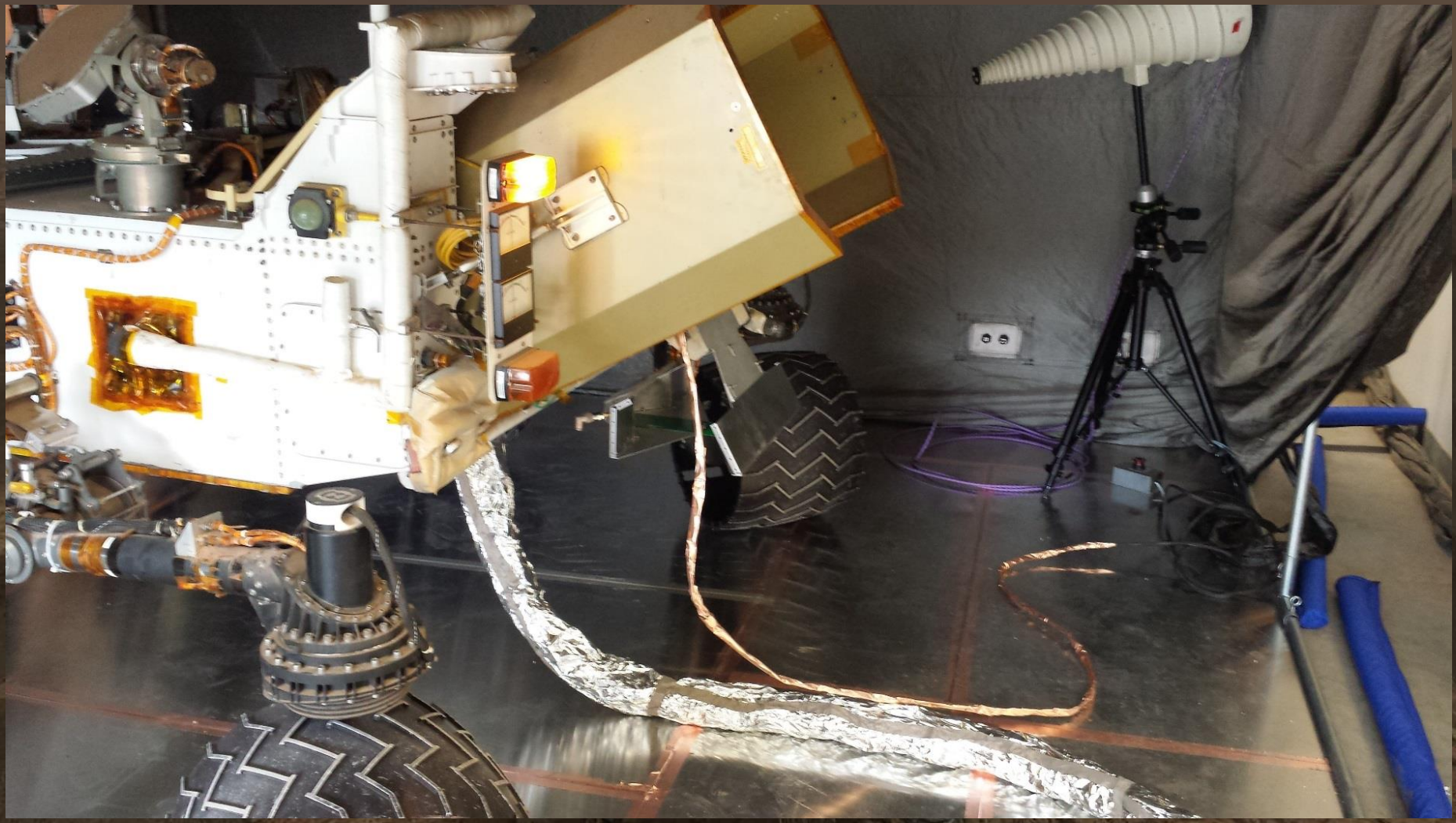
Verification of Tent Performance



Test setup


17'
RF Tent
11'
RIMFAX (shown)
or test antenna
Cable
Bundle
(Shielded)
10'
14'
Bulkhead
Test
Antenna
Preamp
Preamp
EMI Receiver
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
dBuV/m
100.000000
1000.000000
Frequency (MHz)
RE Data
Limit
Proposed RIMFAX limit

Test setup



Receiver settings

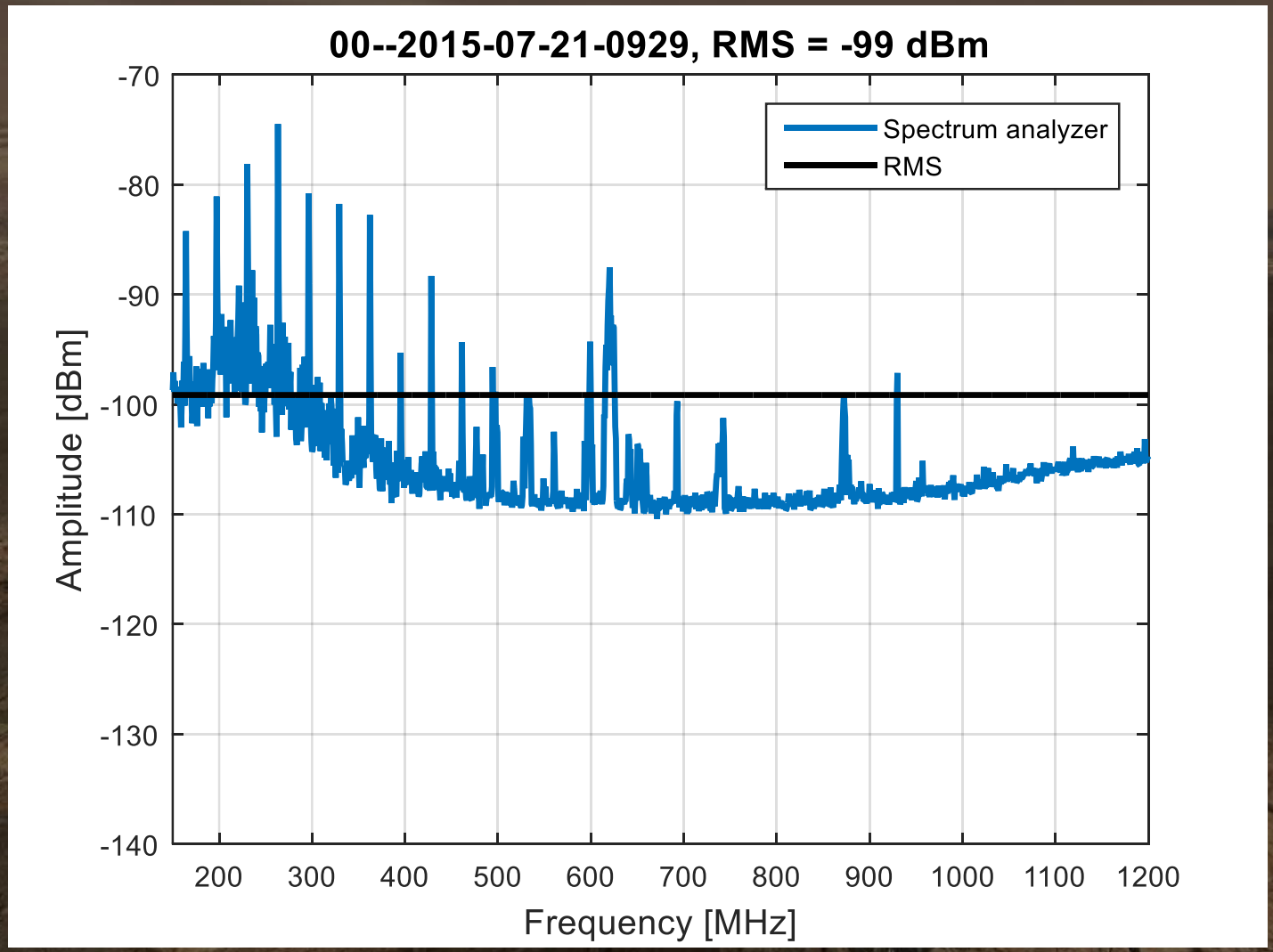
TABLE 1. ACTUAL RIMFAX SOUNDING MODE PARAMETERS (TABLE BY FFI)

RIMFAX Sounding Modes					
Mode Name	Frequency band (MHz)	Sweep time (ms)	Sweeps averaged per sounding location	Samples after downsampling	IF BW (kHz)
Shallow Sounding	150-1200	1.0	100	1450	725
Deep Sounding	150-450	2.5	40	1250	250
Deep Sounding Ex 2	150-450	20	5	3500	87.5

TABLE 2. ACHIEVABLE RIMFAX PARAMETERS WITH RECEIVER

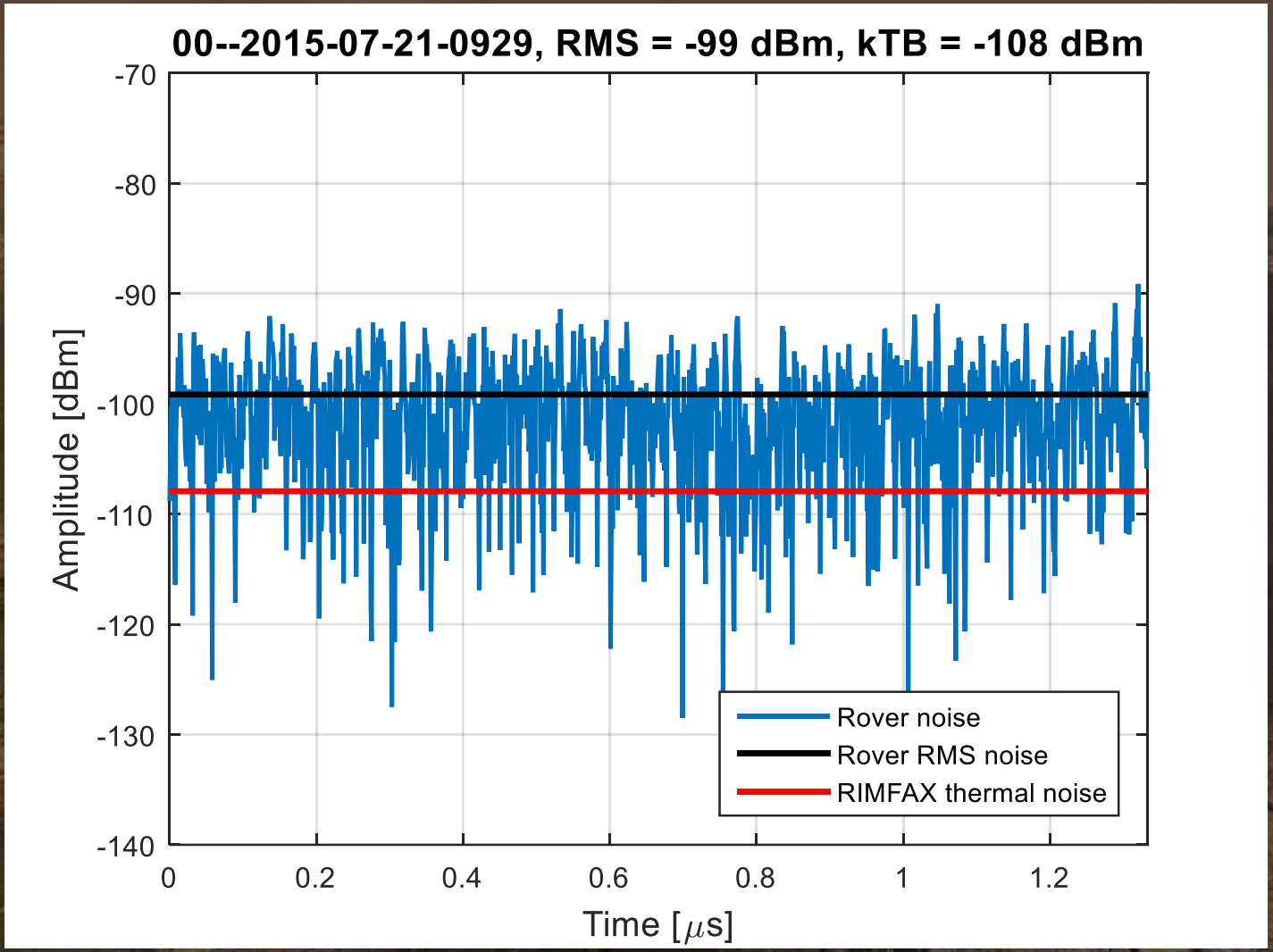
Test Receiver Settings					
Mode Name	Frequency band (MHz)	Sweep time (ms)	Sweeps averaged per sounding location	Samples after downsampling	IF BW (kHz)
Shallow Sounding	150-1200	10	10	1401	500
Deep Sounding	150-450	10	10	1251	300
Deep Sounding Ex 2	150-450	20	5	3501	50

Results: Shallow Sounding Mode



Signal received by RIMFAX prototype antenna in “shallow sounding like” mode

Results: Shallow Sounding Mode: Time Domain



Random phase assigned to frequency, IFFT to time domain

UWB radar figure of merit: SDR

- EMC RE requirements are often specified based on noise-limited receiver sensitivity.
- Based on previous slides, this limit is exceeded
- Science requirements based on UWB radar figure of merit called signal dynamic range (SDR)

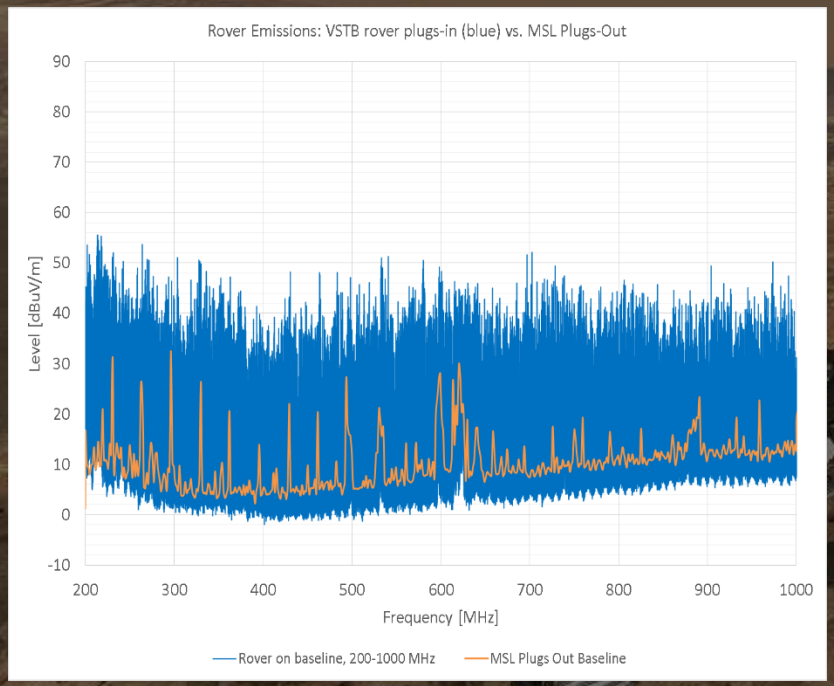
$$SDR = \frac{P_T N_F G^2}{2 k_B T_0 F B_{IF} (SNR)}$$

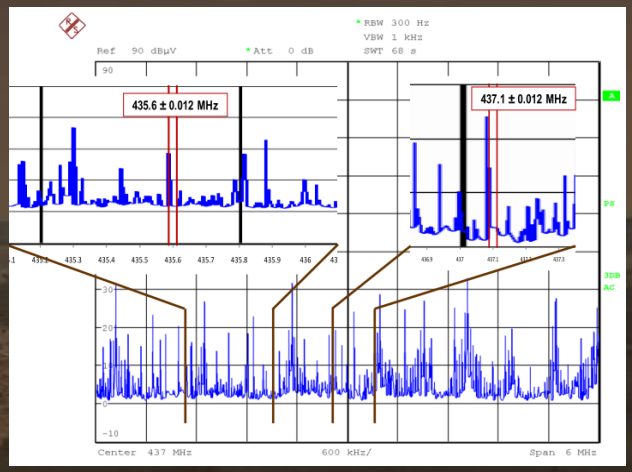
UWB radar figure of merit: SDR

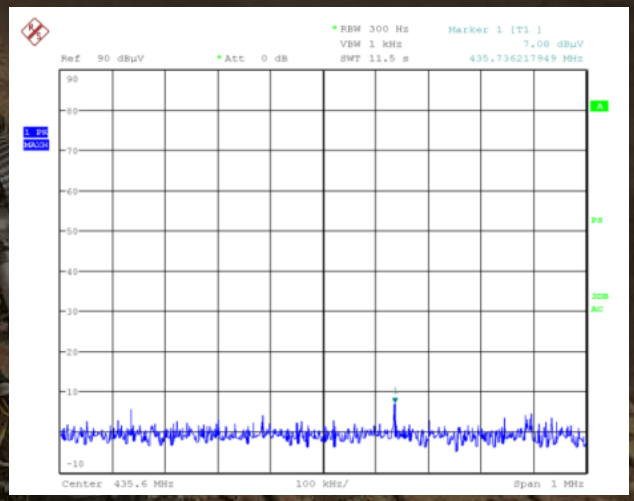
$$SDR = \frac{P_T N_F G^2}{2 k_B T_0 F B_{IF} (SNR)}$$

- The effect of exceeding the baseline thermal noise limit is accounted for by an increase in effective system noise temperature T_0
- However, overall SDR shows that there is in fact 40 dB of margin due to numerous integration points N_F in FMCW radar sweep

Comparison to MSL “Curiosity” and plugs-in condition







On top of existing 40 dB margin from SDR, plugs-in (GSE umbilical connected) is a known worst-case situation both from a fundamental EMC condition and from prior experience on the MSL Curiosity rover

Conclusion

- The RIMFAX UWB ground penetrating radar should provide new insight into the Martian subsurface environment
- The challenges presented rover noise were tested in a controlled RF environment
- Risk to science data from rover noise is expected to be low based on figures of merit used by science team
- Standard EMC figures of merit may not be appropriate for all potential victims